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Human-Systems Integration Technologies, Tools, and Techniques (HSIT³): Pre-Seminar and SOAR Workshop Summary

Interim Report 2

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13. ABSTRACT ***(Maximum 200 Words)***

The Human Systems Integration Pre-Seminar and State-of-the-Art Workshop was held as the initial step toward the advancement of HSI into the next Millennium. The workshop was very successful in three areas. First, the workshop proved to be highly successful in providing a forum for stimulating ideas and discussions among the HSI and MANPRINT experts. Second, it met the objectives of identifying HSI tools, techniques, and technologies for a Seminar in June, a task primarily accomplished by participants of Panel III. Third, and most importantly, the workshop was very productive in answering the objectives of the SOAR development. This included SOAR organization, chapters to include in the SOAR, and in identifying individuals as candidates for chapters.

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Interim Report #2
Human Systems Integration (HSI)
Technologies, Tools, and Techniques Pre –Seminar and SOAR Workshop

1. Background

Over the past decade the U.S. Army has developed a wide range of tools, techniques, and technologies for integrating human factors into material acquisition. Many of these methodologies have been critical to the Army's MANpower and PeRsonnel INTegration (MANPRINT) program, providing a number of cost and performance benefits. The Department of Defense (DoD), U.S. Government agencies, and foreign countries have begun to implement their own programs modeled after the MANPRINT program. These programs are frequently identified as Human-Systems Integration (HSI) or Human-Factors Integration (HFI) programs. However, a major problem has developed with both the Army MANPRINT program and those programs modeling MANPRINT in their attempts to achieve cost and performance benefits similar to those achieved in the past. This is due to the lack of guidelines and case study material describing the methodologies.

Since MANPRINT was introduced 14 years ago, HSI has become more prevalent in system designs. While many accomplishments were made, there is still a tremendous potential for the application of HSI to future systems. To capture the theoretical advances and lessons learned in the development and application of HSI technologies, tools, and techniques, it was determined that a complete state-of-the-art study was needed as the first major step to update, standardize, document, and train for the current HSI concepts and processes. The first task in this study was a survey of the user community to obtain input on user requirements and needs for an updated HSI practitioner's guidebook. The second task was to design and conduct a workshop to investigate the implications of human-systems integration technology advancements and to evaluate the outcomes of various applications of HSIT3.

2. Purpose and Objectives

The Human-Systems Integration Pre-Seminar and State-of-the-Art Workshop was held as the initial step toward the advancement of HSI into the next Millennium. This event provided a forum for HSI subject-matter experts (SMEs) and MANPRINT practitioners to gather and discuss the information needed to support the upcoming HSIT3 seminar, scheduled for June 15-16, 2000 in McLean, Virginia. Additionally, the workshop was designed to instruct potential contributors of the purpose of the proposed state-of-the-art report (SOAR) on Human-Systems Integration, generate consensus on a thematic outline, and select candidate authors. This SOAR will update and expand the original MANPRINT book edited by Dr. Harold Booher in 1990, covering HSI developments during the last decade. The SOAR will be completed in time for a new HSI book to be published around mid-year 2001.

3. Discussion

The HSIT3 Pre-Seminar and SOAR Workshop was held January 16-17, 2000 at the Crystal City Marriott in Arlington, Virginia. Fifty SMEs representing the Army, Navy, Air Force, FAA, NASA, UK, and industry were invited to attend and discuss their ideas for structuring the SOAR and seminar. The workshop was designed to provide an introduction and background on HSI and MANPRINT, provide small discussion groups, and conclude with summary sessions. Of the fifty individuals invited, twenty-eight were in attendance on the first day and twenty-four on the second day.

Prior to the workshop, all invited attendees received a copy of the HSIT3 survey summary document, *HSI Methods and Principles,* to provide them with the ideas, themes, and recommendations that were made on the survey. Participants also received a draft outline of the SOAR that was prepared by the SOAR editor, Dr. Harold Booher. This outline consisted of five Parts and eighteen chapters (Attachment 1). The goal of the workshop was to work within the context of this outline and determine the content of the SOAR, the chapter titles, and select authors for each chapter and identify candidate authors for each chapter.

Since the purpose of the workshop was to discuss and generate a consensus on the topics and focus of the SOAR, participants were invited as potential authors, in which they were asked to submit a short proposal and outline, as panel members, or as panel leaders. The panel members and leaders were chosen on the basis of being able to make a significant contribution to a particular section of the SOAR.

On the first day of the workshop, a Plenary Session was conducted by Dr. Booher in which he provided an overview on the technological needs for HSI and a historical review of MANPRINT failures, successes, philosophy, and principles (Attachment 2). Following this session, participants were assigned to one of five Panel Sessions, each panel corresponding to one of the five Parts of the SOAR. Participants were given a package of material relevant to the part of the SOAR they were assigned to review. This packet consisted of a review of the MANPRINT Principles, as well as a description, the survey results, chapter proposals and outlines corresponding to the SOAR Part to which they were assigned.

The Panel Sessions comprised the remainder of the workshop, with sessions being held both mornings and all afternoon on the first day. While it was desired that the format of the sessions be free flowing so that as many ideas as possible could be discussed, the Panel Leaders were requested to try and guide the conversations to extract answers to the following questions:

- Is this PART reasonable for a Principles and Methods book on HSI?
- Is the proposed PART in the right order with all the other PARTs?
- Could the proposed PART be divided and distributed throughout other PARTs?

- Are the chapters being considered for this PART appropriate or should they be placed in another PART?
- Do ALL the chapters discussed belong to this PART or would some be better in another PART?
- Are there chapters not listed that should be included in the book?
- What specific chapters do you recommend be in your PART?
- For each chapter recommended for your PART, what is your opinion of the proposal status?
- For recommended chapters that have no currently acceptable proposals, can you identify individuals to request proposals?

4. Conclusions

The workshop was very successful in three areas. First, the workshop proved to be highly successful in providing a forum for stimulating ideas and discussions among the HSI and MANPRINT experts. Everyone who participated showed considerable interest and enthusiasm in being able to attend. At least ten other individuals wished to attend, but were unable and expressed interest in being able to participate in the Seminar and SOAR development.

Second, it met the objectives of identifying HSI tools, techniques, and technologies for a Seminar in June, a task primarily accomplished by the participants of Panel III. Third, and most importantly, the workshop was very productive in answering the objectives of the SOAR development. This included SOAR organization, chapters to include in the SOAR, and in identifying individuals as candidates for chapters.

For SOAR organization, all five parts were considered reasonable for a Principles and Methods book on HSI. However, several changes were suggested. These included restructuring the original SOAR outline, deleting several chapters, and adding several new chapters, thereby increasing the net number of chapters from the original 18 to 24. Four principal organizational changes were suggested. First, move the introductory chapter from Part I and make it a separate entity. Second, combine the original Part I and IV into a revised Part I. Third, switch the order of presentation of Parts II and III. And finally, expand the final Part (now Part IV) to include additional case examples. The revised Outline (Attachment 3) reflects these changes.

Outstanding progress was also made in determining the appropriate content for the recommended chapters. The workshop panels reviewed 16 proposals for chapters and provided synopses for most of the chapters. As new information is provided by the HSI Advisory Group and candidate authors, the synopses are continually revised by the editor. The synopses are provided as Attachment 4.

Several candidate authors were also identified through the workshop panel sessions. To date, approximately 60 candidates have been identified for the 24 chapters. Based on Panel Leader recommendations, the quality of proposals, the qualifications of interested chapter authors, and the editor's judgement, authors are gradually being identified and

selected. As the authors are identified, the Human Systems IAC (formerly CSERIAC) will notify authors that they have been selected and the actual writing process can begin with that chapter.

Attachment 1
HSI Methods and Principle SOAR Chapters

PART I:	Introduction
Chapter 1:	Human System Integration (HSI) Concept
Chapter 2:	Systems Acquisition Culture
PART II:	HSI Tools, Techniques, and Technologies
Chapter 3:	Manpower, Personnel and Training (MPT)
Chapter 4:	Human Factors Engineering (HFE) Technology
Chapter 5:	Health Hazards Tools and Techniques
Chapter 6:	Systems Safety
Chapter 7:	Personnel Survivability
Chapter 8:	Special Integration Tools (e.g., IMPRINT)
Chapter 9:	Emerging Technologies
PART III:	HSI Applications in Acquisition Process
Chapter 10:	Requirements Stages
Chapter 11:	Solicitation/Procurement Stages
Chapter 12:	System Design (Performance Tradeoffs)
Chapter 13:	Human Systems Integration Test and Evaluation
Chapter 14:	Data Base Design and Management
PART IV:	Management and Organization Integration
Chapter 15:	Management and Organization Environments
Chapter 16:	ILS Interfaces
Chapter 17:	Systems Engineering Interfaces
Chapter 18:	Economic Factors
PART V:	Case Examples
Chapter 19:	Systems Acquisition - Major (e.g., Comanche)
Chapter 20:	Systems Acquisition - Small (e.g., Fox

Attachment 2
Plenary Session Briefing by Dr. Booher

I. Technological Society Needs for HSI

II. History of Failures

III. MANPRINT Successes

IV. MANPRINT Philosophy

V. MANPRINT Principles

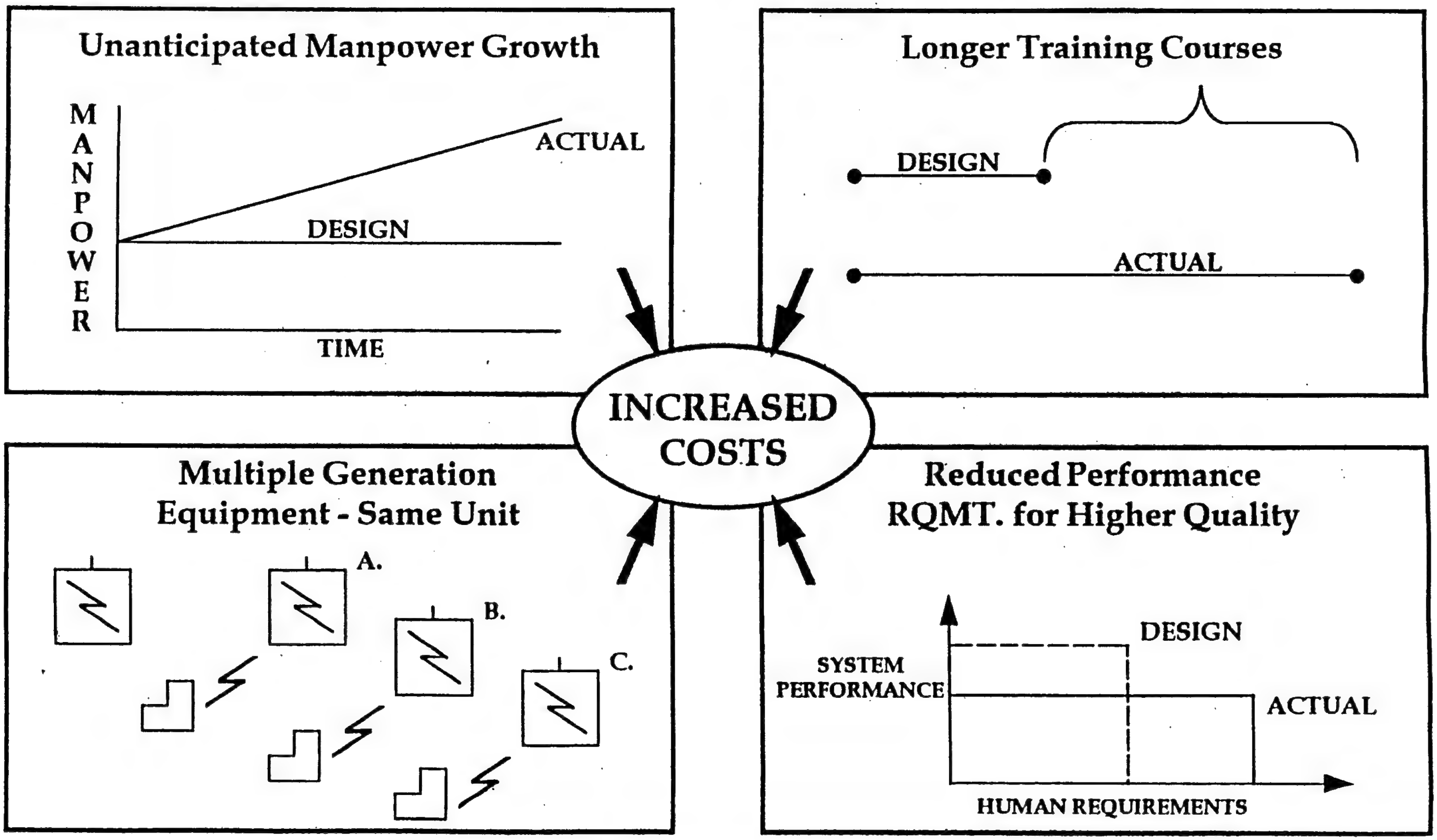
VI. HSI/HFI Adopt MANPRINT Principles

VI. Summary

INCIDENCE OF HUMAN ERROR

- The General Accounting Office reported that over 50% of the failures of military systems are the direct result of human error;
- The U.S. Army Safety Center has reported that 80% of accidents involving Army systems are due to human error;
- An American Nuclear Society Report stated that 90% of facility emergencies involve human error;
- The Office of Technology Assessment estimated that 62% of hazardous material spills were due to human error;
- A Boeing study has attributed 65% of all airliner accidents to human error;
- The Navy Safety Center cited human error as the cause of 85% of ship accidents;
- The Nuclear Regulatory Commission attributed 50% of nuclear power plant accidents to human error;
- The US Department of Transportation states that 90% of all automobile accidents involve human error.

Ignoring the Facts is Expensive



A History of Failures

Major U.S. Governmental Programs in Human Performance Improvement

1965 Air Force Personnel Subsystems Program *Implemented*

1968 Navy Material Command Human Factors Program *Initiated*

1969 Air Force Personnel Subsystems Program **Canceled**

- No evidence of Effectiveness
- Too much documentation

1970 Navy Material Command Human Factors Program **Canceled**

- Admiral Rickover described Human Factors as "egg sucking . . ."

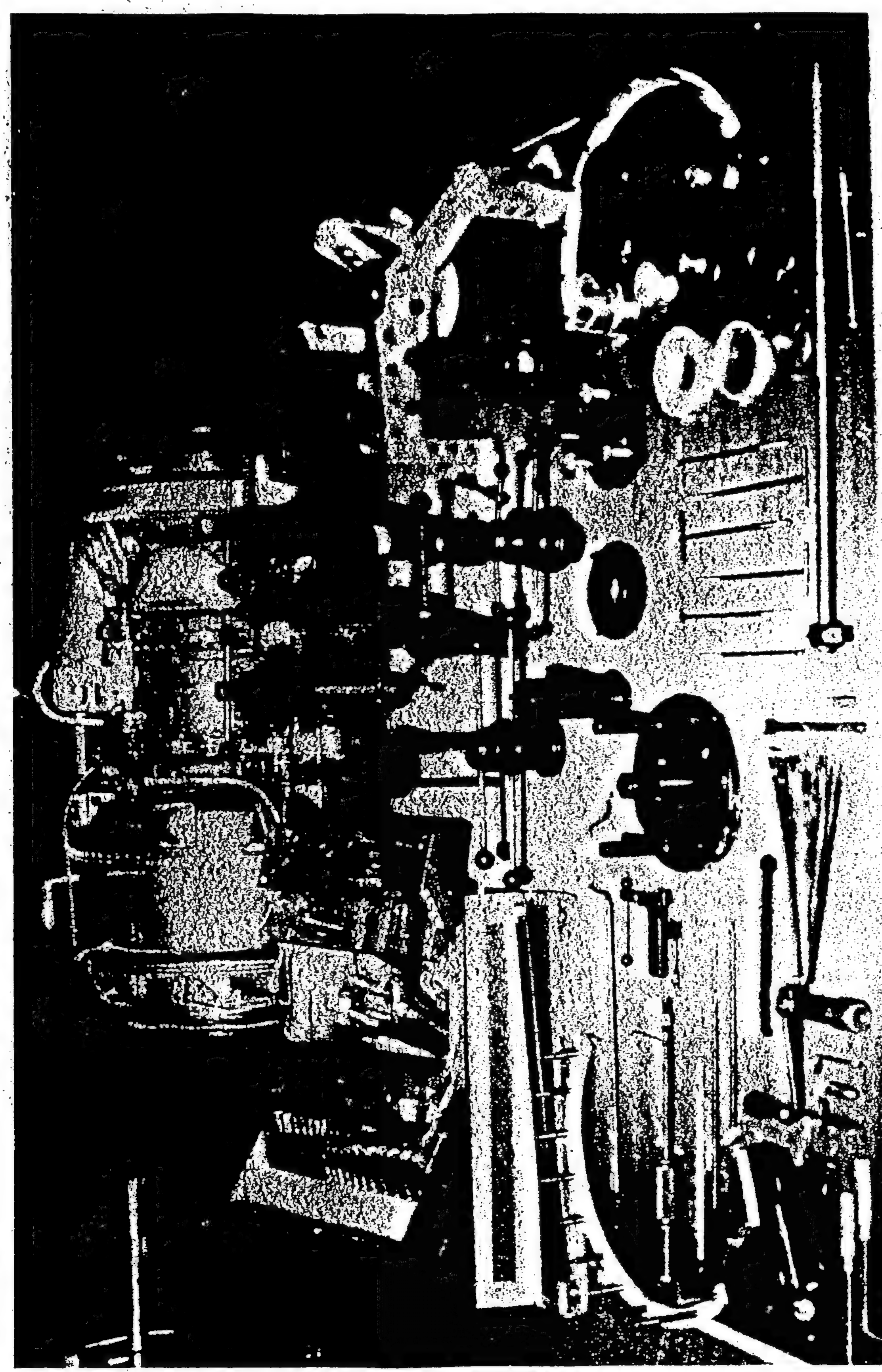
1980 Nuclear Regulatory Commission *Established* Human Factors Directorate as Result of Three Mile Island Accident

1986 Air Force IMPACTS Program *Established*

1990 Nuclear Regulatory Commission **Eliminated** Human Factors Directorate

1991 Air Force IMPACTS Program **Disestablished**

1995 Human Systems Integration ???



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MANPRINT Cost Benefits

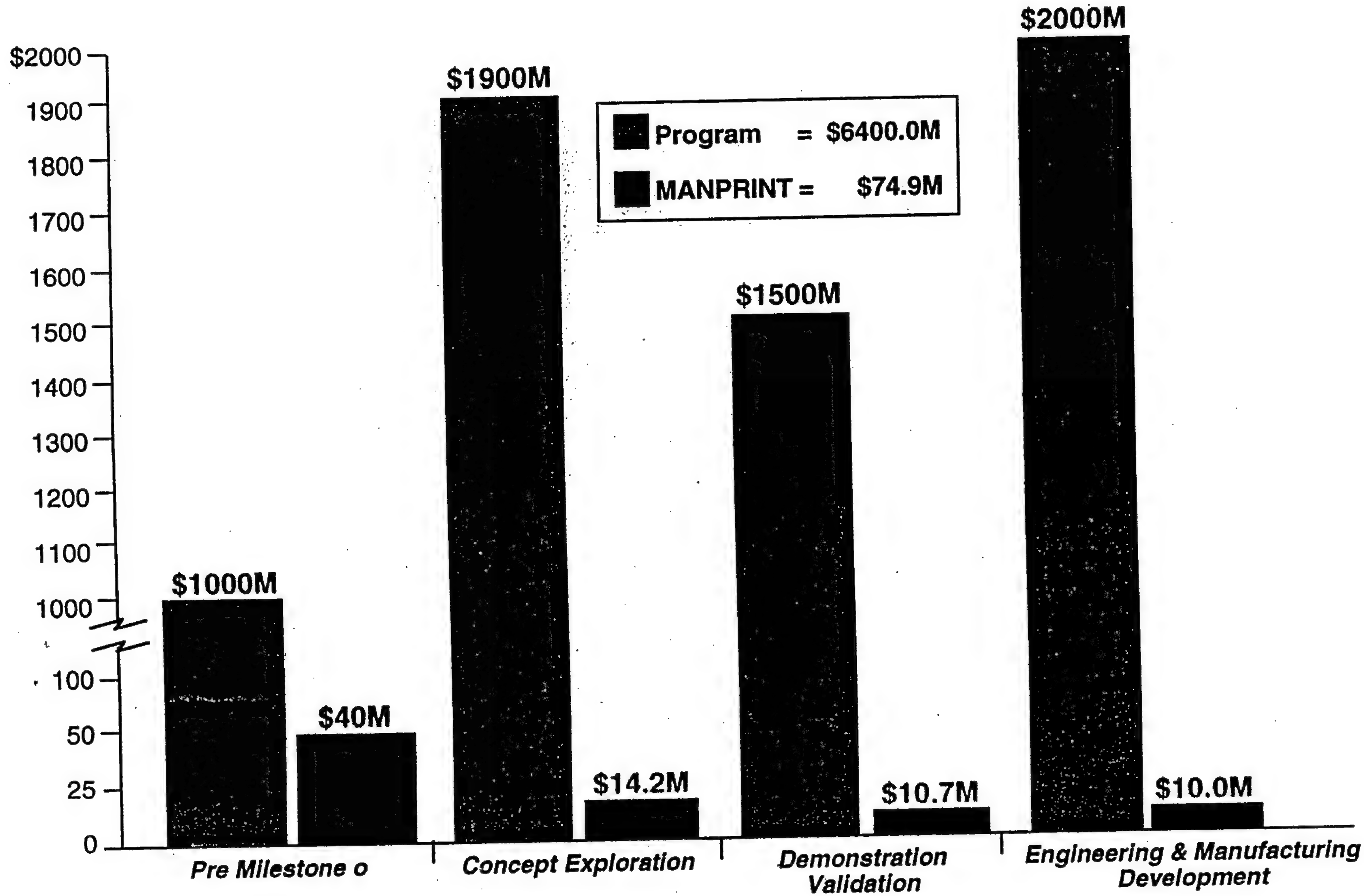
SYSTEM	GOVERNMENT COST	BENEFIT
T-800 ENGINE	NONE	• EASIER MAINTENANCE • FEWER MAINTAINERS • HIGHER RELIABILITY
AVENGER	$300,000	• $61,000,000 COST AVOIDANCE, OR • INCREASED WARFIGHTING CAPABILITY
LOS-F-H	$800,000	• $80,000,000 COST AVOIDANCE, OR • INCREASED WARFIGHTING CAPABILITY
ATHS	$1,500,000	• $1,000,000 PER ANNUM MANPOWER COST AVOIDANCE, AND • INCREASED WARFIGHTING CAPABILITY
M151A2 JEEP ROLLOVER PROTECTION SYSTEM	$20,000,000	• DAMAGE REDUCTIONS: –$285,000 (FISCAL YEAR 87)TO –$21,000 (FISCAL YEAR 89) • NON-FATAL INJURIES: –55 (FISCAL YEAR 88) TO –1 (FISCAL YEAR 90-FIRST 6 MONTHS)

MANPRINT

Impact on Comanche

- Improved Army acquisition process (e.g., Source Selection, TSM-Forward)
- Drove human-centered design - 500 design improvements
- Maximization of total system performance (pilot workload, maintenance ease, personnel safety)
- Cost Avoidance > \$3.29B
- Avoids 91 fatalities, 116 disabling injuries

Comanche MANPRINT Costs vs Program Costs



M costs vs P costs (I)

Major Returns on Investment

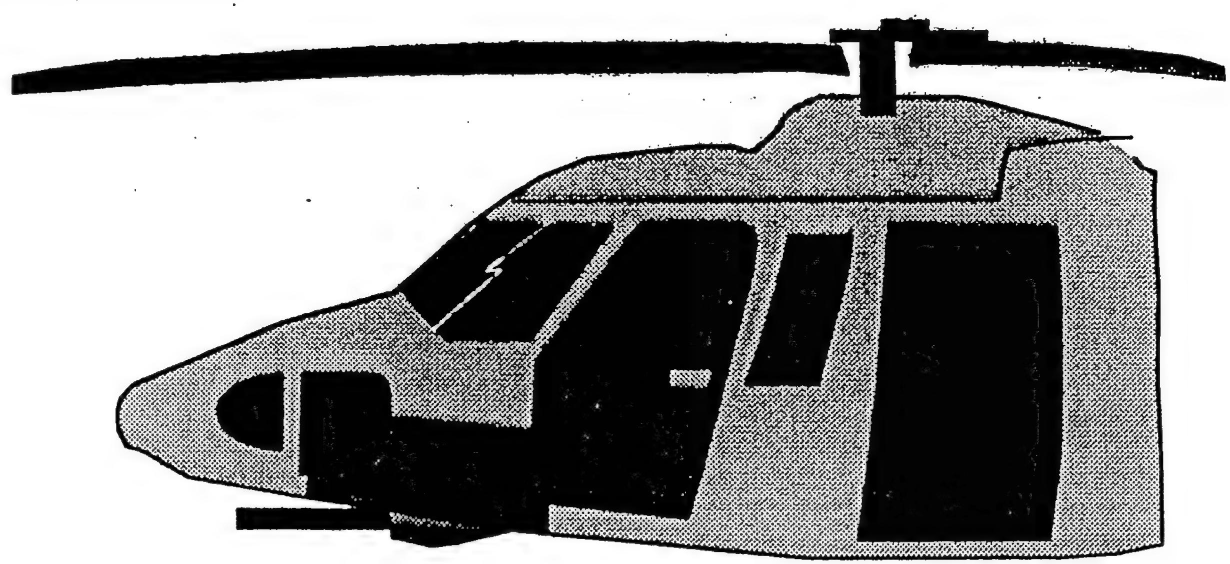
System	Cost Avoidance (CA)	Investment (I)	$\frac{CA}{I}$ Ratio	Time (yrs)
Comanche	$3.29B	$74.9M	43.9:1	20
Apache Longbow	$268.8M	$12.3M	21.8:1	20
Fox	$2-4M	$60K	33.0:1	1

The MANPRINT Approach

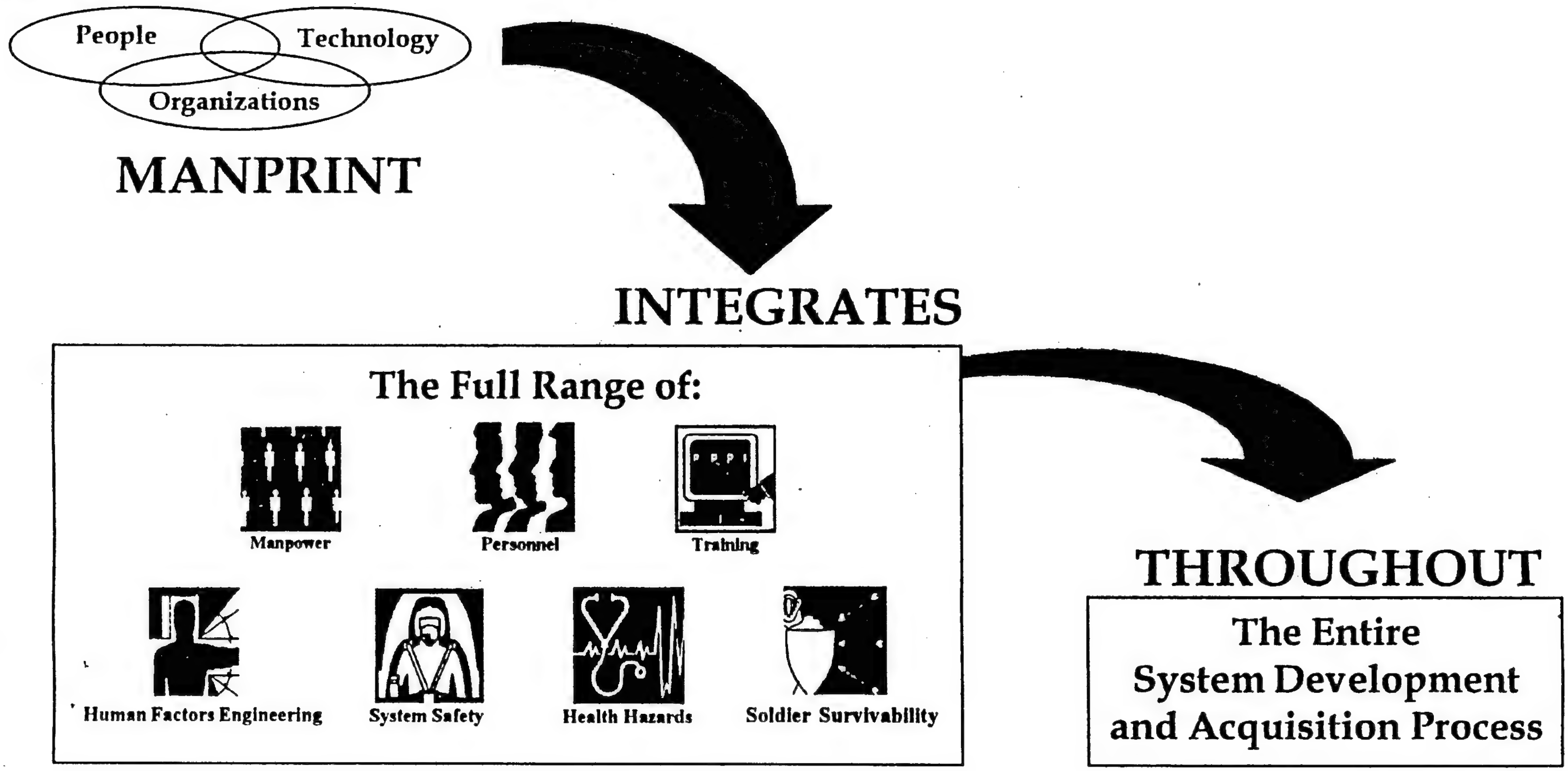
PEOPLE

TECHNOLOGY ← TRADEOFFS → STRUCTURE ↔ ENGINEERING DESIGN → INTEGRATED SYSTEM

TRAINING

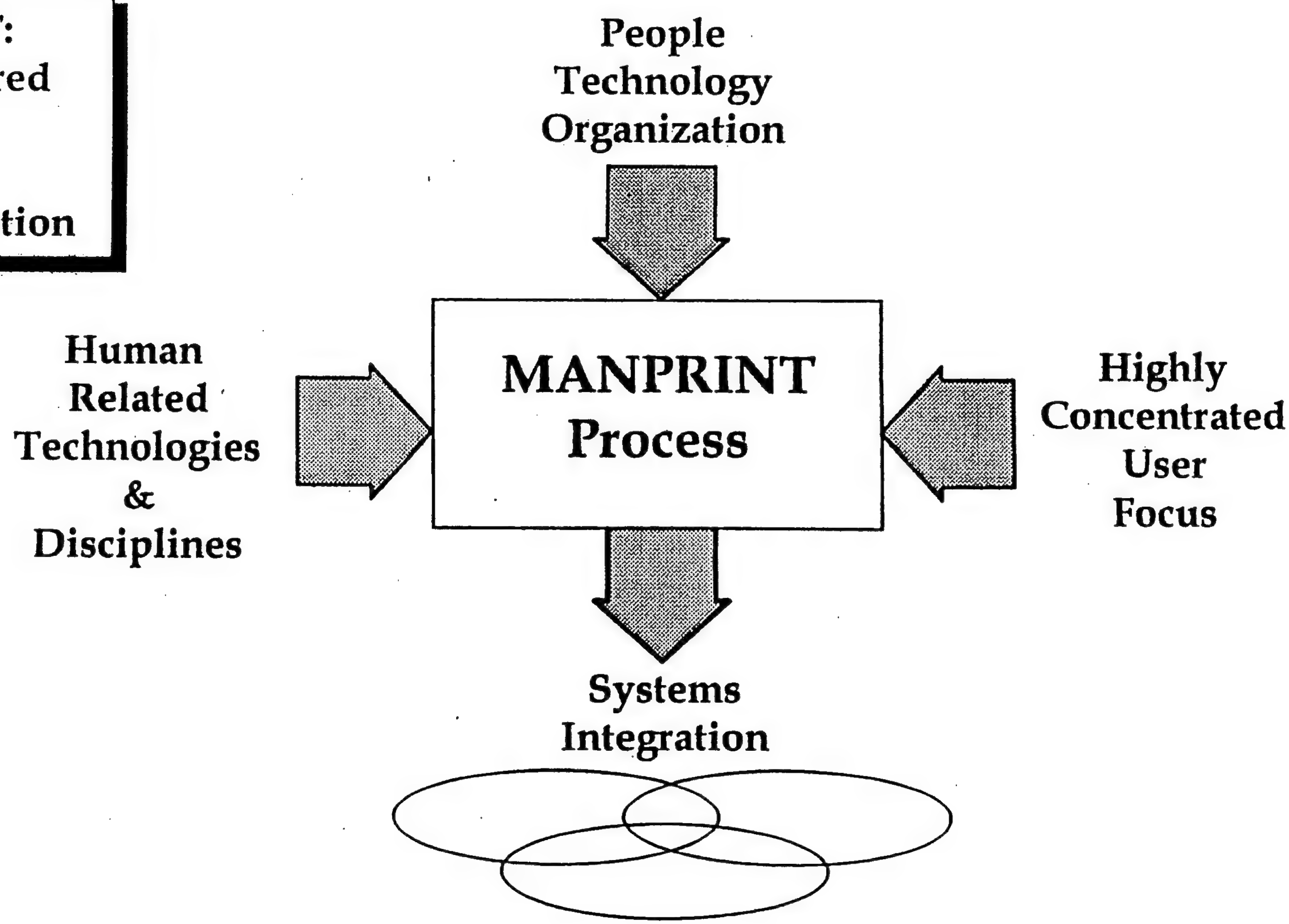


The MANPRINT Concept



The MANPRINT Model

MANPRINT:
Human Centered
Approach
to
Systems Integration



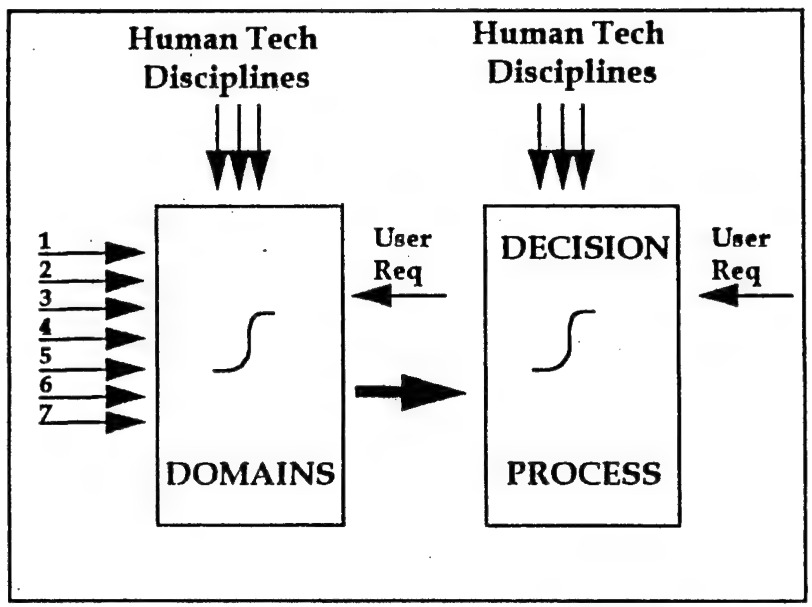
MANPRINT Model Highlights

Human Related Technologies & Disciplines → MANPRINT Process ← Highly Concentrated User Focus

Technologies
- Man in loop simulation
- Human performance assessment
- Human-systems tradeoff methodology
- Cognitive workload
- Anthropometric

Disciplines
- Human Factors Engineering
- Engineering Psychology
- Instructional Technologies
- Manpower/Personnel
- Operations Research

Double Integration



User Requirement e.g., Target Audience Description

- -Cat. I-IV
- -5th-95th%
- -Manpower Level

MANPRINT PHILOSOPHY
UNIQUE ASPECTS -- 1

People-oriented concepts visibility

Total organization competence and motivation

Top-down approach

Multi-disciplinary

Quantification people variables

Early warning techniques

Early trade-off techniques

MANPRINT PHILOSOPHY
UNIQUE ASPECTS -- 2

Demonstrates immediate benefits

Pushes technology

Part of system

Communicates in decision-making language

Encourages resources redirection

Educate all people in process

MPT demand reduction

MANPRINT Model Principles

- Absolute "Real" user focus
- Top level commitment & understanding
- Proof and enforcement of commitment (e.g. source selection and testing)
- Union of all human-centered domains
- Quantitative methodology
- Measures of effectiveness (performance and ROI)
- Tailored to acquisition strategy (e.g., NDI)
- Feed engineering standard practices (not separate bureaucracy)

MANPRINT Principles

- Top level understanding and advocacy
- “Systems” include humans
- Tender evaluation policy
- Organisational integration of all “human factors” domains
- Documentation integration of MANPRINT into acquisition process
- Quantification of human parameters
- Application of trade-off methodology
- Auditing Process integrated with MANPRINT
- Highly qualified MANPRINT practitioners
- Broad MANPRINT education and training program

Summary

- Historically large scale human performance improvement initiatives have failed.
- Ten MANPRINT principles have been identified which appear necessary to achieve clear and lasting benefits to systems acquisition organizations.
- Major returns on investment directly attributed to MANPRINT have been demonstrated on military systems.
- MANPRINT benefits are feasible across the full spectrum of acquisition categories and types.
- Systems which do not adopt MANPRINT (or something equivalent) are highly likely **to fail** to meet their cost, schedule, and performance objectives.

Attachment 3
Revised SOAR Outline

Titles

Chapter 1: Introduction: HSI Philosophy

PART I: Organization/Management Context
Chapter 2: Organizational Environments/Managing Change
Chapter 3: HSI Roles in a Systems Acquisition Culture
Chapter 4: Economic Assessment
Chapter 5: Education and Training

PART II: HSI in Acquisition Process
Chapter 6: Human Systems and Procurement
Chapter 7: Requirements
Chapter 8: System Design (Performance Tradeoffs)
Chapter 9: HSI Test and Evaluation
Chapter 10: Simulation Based Acquisition

PART III: HSI Methods and Technologies
Chapter 11: Introduction to Part III
Chapter 12: Manpower and Personnel
Chapter 13: Training
Chapter 14: Human Factors Engineering
Chapter 15: Health Hazards
Chapter 16: Systems Safety
Chapter 17: Personnel Survivability
Chapter 18: Special Integration Tools
Chapter 19: Emerging Technologies
Chapter 20: Guidance and Standards

PART IV: Examples of HSI Applications
Chapter 21: MANPRINT in Major Army Systems
(Comanche, Crusader, Land Warrior)
Chapter 22: HSI in Small Systems (Govt; Commercial)
Chapter 23: Futuristic Human Centered Shipboard
Systems and Operations
Chapter 24: HSI in Commercial Applications

Attachment 4
Chapter Synopses 2-16-00

Introduction

Chapter 1: Introduction: Human Systems Integration Philosophy

This introductory chapter would build upon the original MANPRINT Book introduction which described the MANPRINT concept of integrating various human systems disciplines and technologies in the systems acquisition process. In the ten years since the original book was published, there has been significant opportunity to further refine the principles which are important to this concept and show historically how systems which do apply these principles are successful whereas those which have not tend to fail to meet their cost, schedule and performance objectives. The original MANPRINT model will be described and recommended as the model for all large organizations wishing to apply this philosophy to their systems acquisition processes. The transition from MANPRINT to Human Systems Integration as the umbrella name for this philosophy will take place in this chapter, so that subsequent chapters may freely use the term Human Systems Integration or Human Factors Integration when referring to this philosophy. This Chapter would introduce the 4 Parts of the book, briefly describing the unique features of each Part and its relationship with the other Parts.

PART I: Organization/Management Context

Chapter 2: Organizational Environments and Managing Change

This chapter deals with two major themes; 1. The impact of organizational environments on the organizational implementation and management of HSI and 2. Motivating and Managing Change introduced by HSI concepts. The Chapter on "Change Management Process" by Blanchard and Blackwood in the original MANPRINT book addressed both of these themes, so therefore, will be the starting point for this Chapter. In discussing the first theme, it is understood that organizational environments include the characteristics and trends in both external and internal environments. External environments include economic, political, military, and technology domains. Internal environments range from to political, social, and cultural aspects of organizations to functional relationships and interfaces - including the frequent "stovepipes" encountered - within an organization. Relationships among these environments are discussed in terms of a layered, ring model of the relationships of HSI to both micro and macro forces and influences. The implications of these environments on HSI strategies, plans, and execution are discussed in terms of impediments to and avenues for organizational implementation and management of HSI specifically. In discussing the second theme. It is particularly important that the particular organization seeking to introduce HSI into its systems acquisition, product development, or operational processes introduce change management concepts which address ways that progress can be made on adopting and continually maturing the 10 principles of HSI into that particular organizational culture. For example, the first principle is top level decision maker understanding and support. This will require therefore a strong business case for HSI and arguments for technology advancements in addition to policies and procedures for implementing HSI into the appropriate management and organizational components. The role of leadership in successful change is stressed, with particular emphasis on sustaining leadership. Other principles

require integration of disciplines and system procurement documentation. In view of downsizing in most organizations, change management must introduce strategies which deal with resistance to change and avoid policies which increase workload on an already strained workforce. One such strategy for affecting change is to get all of the stakeholders to realize that they are already doing much of what is required to introduce a new approach; such that the change is seen as not adding significantly to what they already do; and may even make their job easier and more rewarding. The notion of revolutionary visions and evolutionary plans is discussed, including the factors that affect the likely rate of evolution.

Chapter 3: HSI Roles in a Systems Acquisition Culture

This Chapter covers the Systems Acquisition Culture from four perspectives for its relevance to HSI roles. First is the broad perspective which includes other cultures (e.g., operational environments, research, business, political) interacting with the systems acquisition culture, into which HSI must be immersed; second is the historical perspective which describes the issues that have lead to the current need for HSI as part of the acquisition culture. Third is the specific changes that have occurred over the past 10 years within the Acquisition Culture. Fourth are the changes and trends to the Human Factors culture itself and the ramifications for new HSI roles. In this chapter the primary roles of the HSI players are described for both government and commercial environments. Responsibilities, tasks, decisions, interfaces, etc. for representative roles are considered - a table with myths vs. realities for typical roles is included. The timeline of decisions, roles, and downstream consequences is discussed, including the extent to which each role is a design role and makes design decisions with important downstream consequences. Also considered is how roles are supported in terms of information, organization, resources, etc. and how the nature and extent of this support varies with time/phase.

Chapter 4: Economic Assessment

This chapter begins by clarifying terminology including cost effectiveness, cost/benefit, affordability, total cost of ownership, return on investment, etc., with emphasis on motivations for employing these constructs. Managing tradeoffs and risks, especially financial, is considered. The central equations underlying alternative approaches to cost/benefit analyses are presented, including consideration of the information needed to make use of these equations. Cost justification of longer-term programs such as R&D is compared to assessing the nearer-term benefits and costs of fielding upgrades and innovations such as new technologies. Available historical data are summarized in terms of typical upstream programmatic investments relative to downstream benefits/costs of fielding new technologies. This leads to the general issue of assessing impacts after the fact vs. projecting impacts, both financial and non-financial. Multiple approaches are compared in terms of what information is needed to perform assessments/projections. Finally, the elements of business cases for HSI investments are outlined and practical guidelines for costing HSI in systems engineering language are presented.

Chapter 5: Education & Training

In this chapter, three types of education and training are discussed. First is that needed for HSI professionals who work on the seven domains of HSI. Second is everyone associated with the systems acquisition process; from top level decision makers, to program managers, to all those non-HSI individuals making input to the process. Third is for school systems which teach

advanced courses in HSI. This book is intended to be a valuable contribution to all three types, however, it will be most directly applicable in all of its Parts to the HSI professionals and student Discussion begins with an historical perspective of MANPRINT training and related training programs. Awareness training, technical training, and tailored training for particular product teams are contrasted. Suggested topics and curricula for HSI education and training are presented. Currently available academic programs are reviewed. Advice for students interested in entering the HSI field is provided. Finally, education is considered in the broader context of marketing HSI to senior managers, program managers, and anyone who might be considered a stakeholder in the effects of HSI processes. The Chapter on "National Education and Training" by Muckler and Seven in the original MANPRINT book will be an important resource for this chapter as will be the extensive documentation produced by the MANPRINT directorate on MANPRINT Career Development in the mid-90's.

PART II: HSI in the Systems Acquisition Process

Chapter 6: Human Systems and Procurement

This chapter addresses the relationship between Human Systems Integration (HSI) work and the various procurement processes. These processes define, request, fund and provide authority for effective human systems integration. The process of requesting and contracting for the integration of the HSI domains throughout a system's life cycle is often flawed from the outset. Requirements should be levied and documented in such a manner that they can be realistically satisfied through efficient contract vehicles. The ratified contract provides the required HSI and tasks, the necessary funding, and acceptance criteria for success. As proposed, the chapter will follow the HSI program requirements through the various phases of an acquisition or purchase of a system with emphasis on why certain requirements should be supported. The content of the solicitation and the industry response are examined. Requests for proposal must reflect early trade off analysis, by the requiring community as to what level of HSI is necessary and affordable. Prospective bidders, alerted by a well researched and written solicitation, must then determine and propose the cost of domain and integration levels of effort. Resultant contracts and sub contracts must be clear for essential HSI products and deliverables. There must be a rational objective and contractual obligation for an effective focus on the human in system development. The Chapter ends by listing and describing ten basic "Challenges" to implementing HSI in the Acquisition processes of the government and industry.

Chapter 7: Human System Requirements

The earliest stages of any acquisition program are amongst the most critical. Decisions made at concept will determine whether a project will proceed, define the key risks and issues to be addressed, and determine the allocation of resources for subsequent phases. Human Factors has traditionally been perceived to be limited in its ability to contribute at this phase. Many tools and techniques available have been more suited to analysis to design rather than addressing pre-design concepts and analysis. This has severely limited the ability of HSI specialists to exert intelligence at arguably the most critical stage in the system life cycle. This chapter will discuss the HSI activities that should be undertaken at early concept stages, including a general description of the requirements determination process: the types of HSI requirements and constraints that should be integrated into major project documents; and the role of user information and target audience description. The chapter will then present a promising new

approach, developed within the UK MoD's Corporate Research Program. The overall process is known as the Early Human Factors Analysis (EHFA) and provides a mechanism to cost effectively identify human related risks and requirements early in an equipment acquisition program.

Chapter 8 - System Design and Performance Tradeoffs

Managing life cycle costs requires tradeoffs among critical system components, including HSI domains. A systematic approach to measuring tradeoffs is proposed based on models developed by Meister (1985) and Erickson (1984) that represent human performance measurement as a multi-valenced enterprise driven by a system's goals and sub-goals. The usefulness of a particular measurement procedure is defined by the dimensions of realism (theoretical vs. operational precision) and cost (simple tools vs. complex simulation environments) in relation to the sub-goal a particular measure is addressing. This chapter discusses the advantages and limitations of various measurement techniques, emphasizing the unique measurement problems that the human introduces into the process both in terms of theoretical and pragmatic considerations. The general conclusion is that any sufficiently complex system will require some combination of modeling, hypothesis testing and realistic simulation methods. Examples from an actual Army project (the Unmanned Aerial Vehicle [UAV]) are developed to demonstrate the utility of this approach by highlighting various techniques being used in concert to address both specific performance issues and over all systems effectiveness. Supporting Erickson (1984), it is concluded that an understanding of the hierarchical structure of systems effectiveness and performance issues for a particular system is the most important determinate of a successful human-system measurement process. Inherent to full understanding HSI within a systems effectiveness model is coming to grips with the particular issue of making tradeoffs among HSI domains, such as training costs against manning levels or system safety is a difficult one given the current state of the art. This Chapter addresses the questions “What can we do, and what do we need to be able to do, to facilitate tradeoffs among the HSI domains in order to produce cost effective designs?”

Chapter 9 - Human Systems Integration Test and Evaluation

Test and evaluation is critical to the system development process. Without it one does not know whether the need for which the system is being developed will be satisfied. The following chapter explains how system test and evaluation is conducted by the military services and shows how HSI
issues are addressed in that process. The various kinds of test and evaluation are discussed in the context of HSI. Special emphasis is given to the differences between developmental and operational testing and the advantages and disadvantages of each. The importance of proper test planing is demonstrated and the need to evaluate a system in its total operational context, if as a system of systems, is discussed . Tools and methods for HSI data collection and analysis are examined and discussed with respect to which ones are most likely to produce information useful for integrating the human into the system. Particular emphasis is placed on the need for collection and evaluation of operator and maintainer performance data as opposed to questionnaire data. Finally, HSI evaluation of items that are acquired off-the-shelf with very little user input into the system development process is discussed.

Chapter 10: Simulation Based Acquisition

Modern high level defense studies emphasize the way we fight wars changing from primarily Maneuver Warfare to Information Warfare. It is becoming more and more evident from studies on the irregular nature of information warfare, that modern defense and organizational issues in general must be treated as complex adaptive system issues. (See, e.g., Alberts and Czerwinski, 1997, "Complexity, Global Politics, and National Security," National Defense University). One of the major thrusts in complex adaptive military systems is the need to focus on the complexities of the human element as an information processor if military forces are to be effective in 21st century warfare. This chapter generally discusses the trends and issues in national defense policy, organizations, technology, and personnel driven by 21st century information warfare. It then outlines the impact of these trends and issues on Human Systems Integration roles for the future. For example, advances in information-age technology are changing the system acquisition process. One of these changes is simulation-based acquisition in which HSI plays a central role. The change is based on the definition and development of a high-level architecture that supports the seamless interaction of diverse communication systems, models, simulators, and simulations to provide a realistic context for human in the loop evaluation. In the past, due primarily to cost of establishing a realistic evaluation environment or the immature nature of the system, it has rarely been possible to address inter activity or operational questions until relatively late in the acquisition process. Finally the chapter describes an Army program known as SMART (Simulation and Modeling for Acquisition, Requirements and Training) created to advance the use of interactive models and simulation in system acquisition. Two different applications at the Field Artillery Center and School have demonstrated the value of HSI in simulation based acquisition. A model-test-model approach to support "what if" analyses under a variety of conditions is proposed as a important way to dramatically improve system acquisition in the future.

Chapter 11: Guidance & Standards

In this chapter the spectrum of possible types of guidance and standards are briefly reviewed, including more traditional approaches that are not discussed further. The nature and roles of these approaches are considered rather than their content. The roles of guidance and standards at different points in time are also discussed. The emergent nature of standards is considered, including the effects of market forces and the maturity of technologies and markets. Balancing innovation and stability/risks is addressed, including the need to choose points of substantial innovation carefully. Examples of innovation successes and failures are discussed. A review of best practices is presented based on extensive studies of new product development. This reviews supports the need for an HSI process with appropriate capability maturity characteristics, which are discussed in some detail, including comparisons of approaches from the SEI, ISO, FAA, UK, and others. Evaluation of the outcomes/impacts of HSI processes are considered, with reference to Chapter 4 (Economic Assessment).

PART III: HSI Methods and Technologies

Chapter 12: Human Systems Integration Analysis and Assessment
This chapter provides an introduction to the other chapters in this part. Before the reader can fully

appreciate the following chapters covering the methods and tools for the HSI domains, integration and future trends, the need for this sort of analysis and assessment must be stated. Unfortunately, even for readers of this book, we cannot assume that the need and value-added of HSI methods and tools is understood. This chapter will be addressed more to the program manager or product developer than the analyst or HSI practitioner. A program manager must understand the general rationale as well as the cost-benefit of doing HSI analysis and assessment. It does call for an investment of time, dollars, personnel, and data; and the payoff for the system will probably not be immediate. For example, a dollar savings in crew size is realized only over a system's lifecycle. A design change that will yield a more operable and safer system may incur the short term cost of re-doing specifications. In addition to laying down the rationale and cost-benefit of HSI analysis and assessment, this chapter will introduce the general notions that will covered in the following chapters. Overall, the focus of the chapters in this section is the description of tools, techniques, and technologies for the analysis and assessment of issues across the human systems integration domains. Beyond the core descriptions of the tools, techniques, and technologies, the range of questions addressed include: Why conduct a particular type of analysis and why, or why not, employ a particular tool? When should a tool, technique, or technology be used with respect to system development? What resources are required for effective use, and by resources, we mean time, money, computers, and, perhaps most important, the skills and qualifications of the analysts? Also, what data are required to support a particular tool, technique, or technology? In addition, the integration of methods, tradeoffs among them, pros and cons, and shortfalls, and also, emerging technologies and trends are covered in this section.

Although the preponderance of tools, techniques, and technologies have a strong military emphasis or military derivation, in principle, and increasingly in practice, they have applicability to other government organizations and industry. Where appropriate, relevance outside the military will be pointed out. While many of the tools, techniques, and technologies presented are computer-based, they are not exclusively software products, but include prescribed methods, checklists, databases, and web sites. At the same time, this section does not intend to reproduce the classic human factors engineering texts or measurement or test and evaluation manuals. Rather, this section will present the unique and specific tools, techniques, and technologies developed in the HSI context. Finally, although roughly the same information will be presented in each of the domain chapters, unique analysis and assessment requirements, aspects, demands, etc., and in some cases, legal requirements of each will be highlighted.

Chapter 13: Manpower and Personnel

Manpower and personnel, along with training (MPT), are acknowledged as key domains in HSI. They are key to understanding how individual tasks will be performed, how an overall system will be operated and maintained, and, ultimately, what the person-cost of a system will be. These domains are the essence of the target audience description. However, they are all-too-often overlooked at the very earliest stages of system design. This chapter will cover important manpower and personnel factors that must be addressed in analysis and assessment, with the distinction being made that analysis can be used to feed both design and assessment whereas assessment has more the connotation of a "report card." Note also, that while the manpower and personnel factors that will be discussed apply at some level across industry, the examples are primarily military. Some of the factors are the numbers of people, both operators and maintainers; aptitudes and limits (e.g., cognitive, physical, and experience levels) ; key issues

that need to be addressed (e.g., high driver tasks, matching up skills required by the tasks with the target audience capabilities); contacts and documents that are helpful in doing an assessment; and available methods and tools. Examples of methods and tools that will be covered are task and workload analysis (with a more detailed discussion appearing in the chapter on human factors engineering), the Navy-developed Hardware vs. Manpower (HARDMAN) Comparability Analysis and its follow-on; the Improved Performance Research Integration Tool (IMPRINT); Job Analysis System Software (JASS); the Army Early Comparability Analysis (ECA); the Manpower, Personnel, and Training Decision Support System (MPTDSS); the Army Manpower Cost System (AMCOS); and the Air Force Logistics Composite Model (L-COM). Other factors unique to the military that will be addressed are outside constraints on manpower and personnel (e.g., Congressionally-mandated limits, limits on the recruited and retained populations), the paper trail associated with manpower planning, the large databases of historical personnel data and military job descriptions that are available, and "how-to" handbooks and training courses that are offered. Other themes are the integration of these two domains with each other as well as their natural interaction with the training and human factors engineering domains, and tradeoff decisions. New initiatives underway across the services may be mentioned although detailed discussions will appear in the chapter on the integration of methods and tools.

Chapter 14: Training Intergration Methods and Technology

The central theme of this chapter is that there are methods and tools that are especially appropriate for the analysis and assessment of training as an HSI domain. There are methods and tools for analyzing the training requirements of a set of tasks or an entire system, for determining the effectiveness of a given training technology or approach, and for helping to decide among training alternatives based on cost, effectiveness, and other factors such as length of training, the availability of facilities, and student "through-put" as dictated by external requirements. It is not a discussion of the training technologies and approaches in and of themselves, although some definitions and key references will be provided for types of training such as human-in-the-loop simulation, embedded training, distance learning, team training, etc. Although training has been separated out from the chapter on manpower and personnel, it will be pointed out that the three domains interact, and therefore, the analysis and assessment of the domains must be integrated. In other words, the numbers and types of people and their skill and aptitude levels, along with the task performance requirements will drive the training requirements. Any change to the manpower and personnel parameters or to the task performance requirements will have an effect on training requirements.

The methods and tools described will range from documents and databases to paper and pencil methods and complex models. Some of the candidates for this chapter are listed next: Documents and databases to be described include required government documents, established programs of instruction, personnel summary data, job descriptions, etc. One particular paper and pencil method uses weighted measures of "ease of remembering" and is described in the "User's Manual for Predicting Military Task Retention." An evaluation of task criticality as it relates to training requirements can be accomplished through the Army Early Comparability Analysis (ECA) procedure. Estimates of time to learn can be provided by the very detailed Goals-Operators-Methods-Selection Rules (GOMS) approach. Sensitivity of task performance to recency and frequency of training can be examined using the Improved Performance Research Integration Tool (IMPRINT). The linking of task characteristics to training requirements can be

addressed through the method proposed in the Manpower, Personnel, and Training Decision Support System (MPTDSS). Training method and device selection as a function of effectiveness and cost can be guided by a model developed by the U.S. Army Training and Doctrine Command Analysis Center at White Sands Missile Range where training cost-effectiveness analyses are conducted.

Finally, noteworthy training issues will be raised. There will be a discussion of issues raised by the peculiar, but increasingly pervasive, rapid train-up requirements of National Guard and Reserve components. Any insights gained into the training requirements being introduced by computer automation on the battlefield, particularly as it relates to vast differences in computer experience levels among new recruits and re-training of the older workforce also will be shared.

Chapter 15: Human Factors Engineering (HFE) Technology

This chapter will outline the methods and tools associated with conducting human factors engineering (HFE) during system design, development, testing, and throughout the life-cycle of military systems. As discussed the HFI domain is considered a critical part of the systems engineering process. HFE has supporting technologies that are useful at all phases of systems engineering. The chapter discusses a wide range of technologies and methodologies, including mockups and rapid prototypes; usability assessments, human figure models; checklists, standards and handbooks, and expert systems. The chapter is especially comprehensive in its coverage of human figure models because of the important role they play in the systems engineering process. The state of the art for human figure models includes classes of models by purpose; issues in building HFM for human factors analysis; issues in selecting a model and tool for a project; basic features and steps in using HFM tools; and future development in HFM.

Chapter 16: Health Hazard Assessment Tools and Techniques

This chapter contains a brief description of health assessment requirements contained in Department of Defense and Army Regulations since they differ slightly from other HSI/MANPRINT domains. It also contains a brief description of the Army's HHA Program, the nine health hazards that are addressed, the type of health professional/subject matter expert routinely employed to address the hazards, and a definition and typical source of each hazard. A description of military-unique and non-military unique hazards is provided. The chapter focuses on the Army's HHA Program but also includes those tools and techniques used by other services which are currently available. The health hazards and associated tools/techniques are described in nine categories: acoustic energy, biological substances, chemical substances, oxygen deficiency, radiation (non ionizing and ionizing) energy, shock (not electrical), temperature extremes, trauma, and vibration. Sub categories of hazards are contained within some of the overall hazard categories.

Chapter 17: System Safety Tools and Techniques

(TBD) NTSB/Navy

Chapter 18: Personnel Survivability Methodology

Personnel Survivability is the newest domain covered by HSI. Although survivability efforts for protection of the Soldiers and Sailors have been made for thousands of years, the multitude and the technical complexity of today's weapons and threats to military personnel beg for a semi-systematic means to assure that each of the probable threat areas will be addressed thoroughly. Today's threats to the military person or to the equipment he or she uses include, but are not limited to: conventional ballistics; nuclear, biological, and chemical; nuclear, biological, and chemical contamination survivability; Information Operations; directed energy weapons; electronic warfare; and electromagnetic environmental effects. This domain is a source of information which poses a possible methodology to use in pulling together the myriad of Survivability, Vulnerability, and Susceptibility efforts which are being performed today for the military services. The chapter primarily addresses this area for use by the HSI practitioner in a military environment. However many of the principles and techniques of this domain are applicable to nonmilitary applications such as police protection and fire fighting and are discussed as well.

Chapter 19: Special Integration Tools and Technologies

The purpose of this chapter is to provide a discussion of the importance of providing tools to the acquisition community that are explicitly designed to examine the integration of the HSI domains. In the first section (Introduction) we discuss the practical aspects of the tradeoffs between HSI domains during system design. For example, a design that minimizes manpower demands might generate very high training demands. Therefore, the tradeoffs between domains must be considered quantitatively and using a common measure of system effectiveness. Potential measures of effectiveness will be categorized and described (cost, performance efficiency, performance quality). The need for a quantitative measure has driven development of integration tools towards modeling and simulation technologies. The second section (Technical Accomplishments) focuses on the technical advances made by each of the US military services, as well as efforts in the UK and Canada, towards developing tools to support the tradeoff process. Each organization has a slightly different perspective, partly because of their difference in mission, and partly because of the scale of the types of systems they procure. These differences are highlighted and used as a basis for providing the reader with an understanding of the distinctions between the tools. The final portion of this chapter is used to set the stage for Chapter 20 (Emerging Technologies) by focusing on the gaps in current integration technologies and why they exist. These gaps consist of items like the lack of coverage of the Safety and Health Hazards domains, the immaturity of the way in which integration tools handle Survivability, and the difficulty in predicting performance quality. It will also discuss the reliance of powerful tools on human performance research and the need to bolster tool development with empirical studies.

*Chapter 20: Emerging HSI Technologies

The previous chapters in this PART focus on the state-of-the-art for HSI methods and technologies currently being utilized. This Chapter describe HSI technologies which are feasible but are not fully ready for application - these are the emerging HSI technologies. Three general

areas are discussed which can be classified as emerging technologies. First is advanced tools for examining and modeling human-machine system performance (examples include virtual environment technology, web-based tools; interactive CD ROM, SMART behavioral and physiological assessment technologies; massively parallel computational systems; knowledge management and "data mining" technologies. Second is advances in HSI tool integration. The ONR funded project for Human Centered Design Environment (HCDE) is described as the most fully developed prototype. The third area for emerging HSI technologies is [:xxxxxxx]

PART IV: Examples of HSI Applications

Chapter 21: Army MANPRINT Applications on Major Systems

The best examples of all ten HSI principles being applied on major defense systems has been the Army MANPRINT program. Three major army systems - Comanche; Crusader; and Land Warrior are reviewed as case studies for key features described in the earlier chapters. These three systems represent a defense aviation system, an artillery vehicle system, and an individual soldier system. The MANPRINT programs for these three systems are described and evaluated for how well they applied the ten HSI principles. Any new acquisition concepts; system design characteristics; safety improvements; and costs avoided due specifically to MANPRINT are discussed. On the Comanche, for example, more than 500 design improvements could be attributed to MANPRINT; 92 lives were saved; and $3.29 Billion was avoided in manpower, personnel, training, and safety costs. This represented a return on investment for HSI costs of more than 40 to 1. Comanche also introduced such human centered acquisition initiatives as advanced modeling and simulation in concept exploration stages; MANPRINT source selection policy; integrated product teams; and Quantitative Trade and Comparative Analyses.

Chapter 22: HSI Applications to Small Systems

The ten HSI principles were developed with major acquisition programs in mind. In view of changing acquisition philosophy in defense in which more "off the shelf", "non-developmental" products (which do not require long stages of development) are being procured; the question of degree of HSI relevance is often raised. This is also an important issue for small commercial procurement from other commercial suppliers. Is there any advantage to doing HSI for small programs; and if so, is there adequate time; and finally, what should HSI look like that focuses on small, rapidly procured systems. This Chapter covers the above questions on both small, rapidly fielded systems and equipment and small commercial procurements. Specific military examples include the Army's FOX, Lightweight Howitzer, and Armored Gun Systems. Specific commercial examples include selections from those compiled by Hendrick (1996).

Chapter 23: Human-Centered Shipboard Systems and Operations

One of the greatest challenges for Navy Ships of the 21st century is managing workload and optimizing manning efficiency in future naval combatants. The human centered concepts and technologies currently being developed by the US Navy can truly revolutionize the design of both shipboard systems and shipboard work. Many of the HSI concepts and technologies described in earlier chapters of this book focus on manpower, personnel, and training related to single systems. This chapter describes how HSI can be applied far more widely- to all of the manned systems and all the manpower on a destroyer or carrier, for example. This chapter describes the results of various efforts to apply HSI technology to manning issues in future

destroyer DD-21 and Advanced Carrier Design. It also describes new Navy HSI technologies like the Multimodal Watchstation (MMWS) and the Human Centered Design Environment (HCDE) which allow a task-centric approach to system design. Centering the design of the human-computer interface and supporting data and knowledge infrastructure - on the tasks to be accomplished - not on the databases, applications or shipboard systems - is the core of the concept. Designing for the "human processor "- in concert with those designing from the network-centric approach - could be a critical lynch pin of success for reduced manning in the navy's 21st century combatants. This chapter explains task-centric and network centric design concepts and provides scenarios for watch standing in the 21st century destroyer and carrier environments.

***Chapter 24: HSI Applications to Medical Environments**